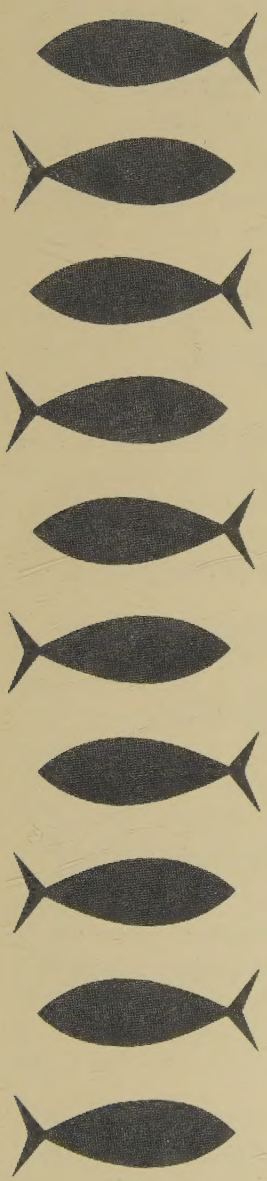
Southwest
FISHERIES SCIENCE CENTER

HONOLULU LA JOLLA MONTEREY TIBURON

REPORT OF ACTIVITIES October-December 1994



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ANTARCTIC ECOSYSTEM RESEARCH GROUP

La Jolla, California

1994-95 AMLR Field Season

The Antarctic Ecosystem Research Group (AERG) made plans for the Antarctic Marine Living Resources' (AMLR) 1994-95 field season in the Antarctic. The AMLR field research is conducted in the vicinity of Elephant Island, which is part of the South Shetland Islands at the tip of the Antarctic Peninsula. As in previous seasons, the field research will be conducted from aboard the NOAA Ship *Surveyor* and also at a field camp on Seal Island, a small island off the northwest coast of Elephant Island. This season will also include shipboard research around South Georgia, a sub-Antarctic island in the South Atlantic.

The AMLR program conducts research in support of the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR); the United States is a member of this international treaty. CCAMLR seeks to conserve all Antarctic organisms *and* to maintain their ecological relationships, often referred to as the "ecosystem approach." CCAMLR stipulates that the harvest of Antarctic organisms will be managed so as to maintain the integrity of the entire ecosystem.

The foundation of the Antarctic pelagic ecosystem is Antarctic krill, *Euphausia superba*. Krill are the main food source for many animals, including whales, penguins, and seals. In addition, krill are harvested by a multinational commercial fishery, part of which is located in the Elephant Island area. Many penguin and fur seal breeding colonies are also located in this area, causing concern that the krill fishery could adversely impact these breeding colonies. The AMLR field program is designed to describe the functional relationships between the krill, their predators, and key environmental variables in the Elephant Island area. CCAMLR's goal is to manage the krill harvest so as to minimize the impact on these animals.

During past cruises, shipboard mapping of the waters around Elephant Island indicated that several water masses converge in the area, forming a hydrographic front along the shelf break north of the island. High densities of phytoplankton and krill are associated with the position of the frontal zone, although the seasonal timing of their appearance can vary by several weeks. This year's field program will continue to be a combination of descriptive surveys of the pelagic ecosystem in the Elephant Island area. In addition, a third cruise leg will be conducted around South Georgia, which will be devoted to a survey of Antarctic crabs in that area.

Land-based studies began on November 30, 1994, when the field camp on Seal Island was opened. The first field team arrived via the motor vessel *Explorer*, a private tourist ship. The original field team included John Bengtson, Mike Cameron, Lisa Hiruki, John Jansen and William Meyer, all of the National Marine Mammal Laboratory (NMML), and Rennie Holt of the Southwest Fisheries Science Center (SWFSC). On December 16, Bengtson, Cameron, and Meyer embarked aboard the Japanese research vessel *Kaiyo Maru* to take part in cooperative studies on the interaction between krill and krill predators (penguins and seals). Bengtson and Cameron returned to the United States in late December via *Kaiyo Maru*, and Meyer returned to Seal Island.

On January 14, Peter Boveng (NMML) and Bill Cobb (SWFSC) will arrive at Seal Island via the *Surveyor*. Later that month, Boveng, Jansen, and Hiruki will embark aboard the *Kaiyo Maru* to participate in more cooperative studies with Japanese researchers; these three personnel will return to Seal Island in late January. In early February, Meyer and Boveng will conclude their field duty, leaving Holt, Hiruki, Jansen and Cobb to complete the Seal Island studies. Throughout the season on Seal Island, research will concentrate on the reproductive and foraging behaviors of penguins and seals breeding on the island. The field team will remain on the island through early March until they are retrieved by the *Surveyor*.

Shipboard studies will begin when the *Surveyor* departs from Punta Arenas, Chile, on January 11, 1995, to begin Leg I, which will last 26 days. A large-area survey will be conducted around Elephant Island to map meso-scale (10's to 100's of kilometers) features of water mass structure, phytoplankton biomass and productivity, and zooplankton constituents. A small-area survey to map micro-scale (1 to 10's of kilometers) features of the distribution, density, and abundance of krill immediately north of Elephant Island will also be conducted. Following a short port call in Punta Arenas, the *Surveyor* will return to the Elephant Island area to repeat these two surveys during Leg II, which will conclude on March 4, 1995.

Following another short inport, the *Surveyor* will depart Punta Arenas on March 8 for a 5-day transit to South Georgia. During this 32-day Leg III, George Watters (SWFSC) will direct studies whose main objective is to determine the abundance and habitat of Antarctic crabs. Using a Seabeam system, Watters and other scientists will conduct bathymetric mapping surveys between the 100- and 350-meter depth contours surrounding South Georgia. These surveys, designed to reveal salient features of crab habitat, will be conducted during dark hours. The ship will follow tracklines oriented to prevailing bathymetry, surveying a small rectangular area daily. During light hours, a remotely operated vehicle will be deployed inside the most recently surveyed rectangular area to obtain abundance estimates of the crabs. Leg III, and thus the AMLR field season, will conclude on April 8, 1995, when *Surveyor* returns to Punta Arenas, Chile. Scientific personnel will return home, and the ship will proceed with her northbound transit, returning to Seattle on May 15, 1995. (J. Rosenberg, 619-546-5600)

COASTAL FISHERIES RESOURCES DIVISION

La Jolla, California

Bathymetric Demography and Ecology of Thornyheads

The continental slope off the west coast of North America is a harsh, poorly studied environment characterized by low temperature, low light, and high hydrostatic pressure. There is often an oxygen minimum zone (OMZ) centered at about 800 m where oxygen concentrations are below 0.5 ml l^{-1}. The physical conditions and absence of primary production result in secondary productivity, growth, and metabolic rates that are lower than in shallower, more productive shelf habitats.

Despite harsh conditions, a number of fish species occur on the slope in commercially exploitable numbers. Two of these, the shortspine and longspine thornyhead rockfish, *Sebastolobus alascanus* and *S. altivelis*, are landed along the west coast of North America from California to Alaska. In the United States between California and Washington, thornyheads are harvested by a deep-water, bottom-trawl fishery that also targets Dover sole, *Microstomus pacificus*, and sablefish, *Anaplopoma fimbria*. During 1993, the U.S. fishery landed approximately 9,000 metric tons (t) of thornyheads worth about $10 million in the face of increasingly restrictive quotas and regulations. Little is known about the life-history or biology of thornyheads despite their commercial and economic importance.

Fishery biologists Russell Vetter and Larry Jacobson used NMFS research trawl data to characterize the bathymetric demography and ecology of shortspine and longspine thornyheads at sites off Oregon (two cruises during 1988 and 1989) and central California (one cruise during 1988). Sampling was conducted between 200 and 1,400 m during the winter and spring. The study sites were chosen because of differences in their bathymetry and history of exploitation.

Shortspine thornyhead ranged from 7-74 cm total length (TL) while longspine thornyhead ranged from 5-37 cm TL. Shortspine thornyhead at both sites occurred at shallower depths than longspine thornyhead and small (20 cm TL) shortspine thornyhead were seldom found at depths greater than 600 m (Fig. 1). Longspine thornyhead settled in deep water and were never taken at depths shallower than 400 m (Fig. 2).

Shortspine thornyhead migrated ontogenetically by moving deeper with increasing size although a

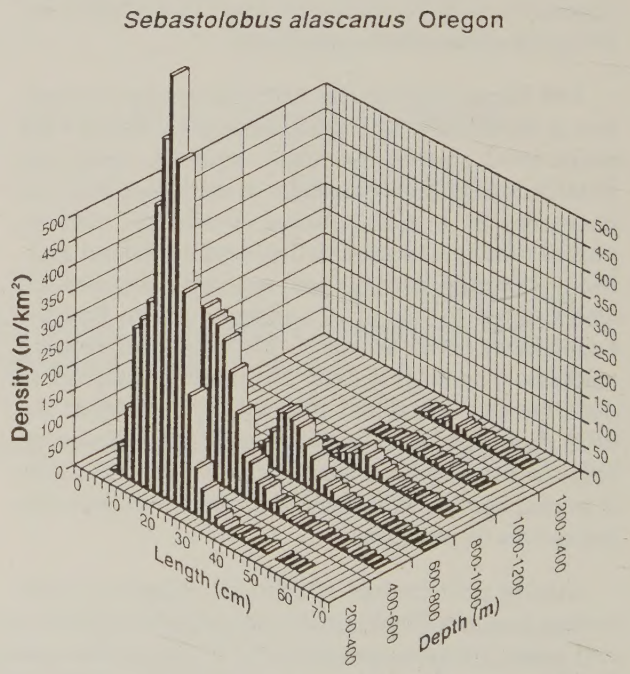

Figure 1. Estimated densities of shortspine thornyhead, *Sebastolobus alascanus*, off Oregon by length group and depth strata.

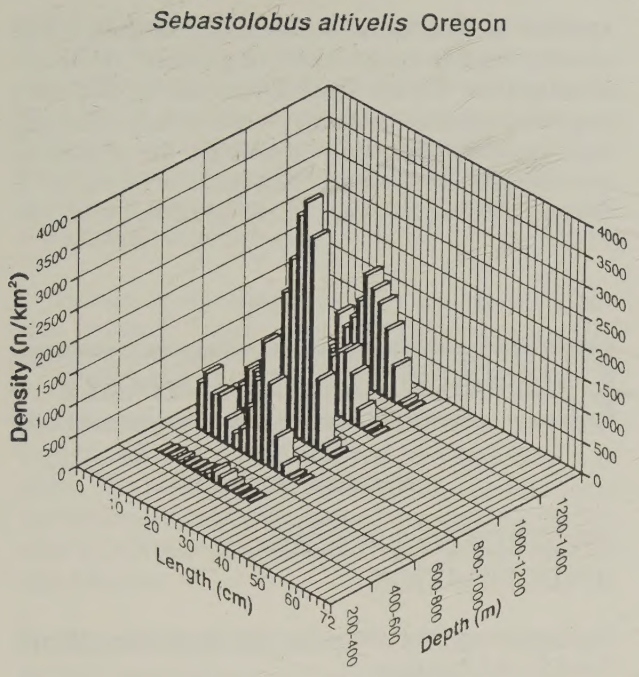

Figure 2. Estimated densities of longspine thornyhead, *Sebastolobus altivelis*, off Oregon by length group and depth strata.

few large fish were present at all depths. Mean size of shortspine thornyhead increased with depth and average size was greatest at 1000-1400 m (Fig. 1). Longspine thornyhead exhibited no ontogenetic pattern of migration and mean size was similar in all depth strata (Fig. 2). There was little overlap in size of shortspine and longspine thornyhead at all depth intervals except 400-600 m. Shortspine thornyhead at 200-600 m were larger off central California.

Estimated numerical densities (fish/km^2) of shortspine thornyhead were similar at 600-1200–m depths off Oregon and central California as were the numerical densities of longspine thornyhead, although there were significant differences in the deepest (1200-1400 m) and shallowest strata (200-600 m). Off Oregon, the density of small shortspine thornyhead at the shallow end of their depth distribution (200-600 m) was high and the density of longspine thornyhead at the shallow end of their distribution (400-600 m) was low.

Biomass densities (t/km^2) for each strata were similar at the two study sites for both species. Biomass densities for shortspine thornyhead in shallow water off Oregon were similar to biomass densities off central California despite differences in numerical abundance because mean size was lower off Oregon. Biomass of shortspine thornyhead was relatively constant across depth strata while longspine thornyhead peaked sharply at 800-1,000 m. The spawning biomass for both shortspine and longspine thornyheads at both sites occurred mostly in the OMZ from 600-1,000 m.

The results of this study indicate that shortspine and longspine thornyhead cannot be characterized simply as shallow- and deep-living congeners. Differences in the bathymetric demography of shortspine thornyhead and longspine thornyhead appear to reduce the potential for interspecific competition because the two species live at different depths when they are the same size. At depths greater than 600 m where maximum overlap occurs, shortspine thornyhead are nine times heavier, on average, and probably predators rather than competitors on the more abundant, but much smaller, longspine thornyhead.

High numerical densities of small shortspine thornyhead at 200-400 m in the Oregon study site was a conspicuous feature in our data (Fig. 1). As described above, biomass densities at 200-400 m were similar, despite the lower numerical density in the central California site, because mean body weight of shortspine thornyhead at 200-400 m was smaller off Oregon. According to a recent stock assessment by NMFS, landings from the Columbia Area (which contains the Oregon study site) were more than six times greater than from the Conception Area (which contains most of the central California study site). In addition, logbook data indicate that most of the fishing effort was concentrated in relatively shallow (400 m) water. Thus, high recruitment of small shortspine thornyhead in shallow water off Oregon occurred where fishing was relatively heavy and may have been due to removal of predators and competitors. (R. D. Vetter, 619-546-7125, and L. D. Jacobson, 619-546-7117)

Sardine Biomass Estimated (CalSAFE Program)

J. Thomas Barnes, associate marine biologist of the California Department of Fish and Game (CDFG) and Coastal Division staff collaborated on a biomass estimate for Pacific sardine in 1994. The work was the first project completed under the California Stock Assessment and Fishery Ecology (CalSAFE) Program recently established by the Southwest Fisheries Science Center and CDFG. CDFG used the biomass estimate to set a quota for the California fishery during 1995.

Daily egg production (DEP) estimates for 1986 and 1994 were new and important sources of infor-

mation for the sardine biomass estimate. Sampling for the 1994 DEP estimate was conducted during March-May in a field program undertaken cooperatively by the Mexican Department of Fisheries, scientists at Mexican Universities, CDFG, and the Southwest Fisheries Science Center. Ichthyoplankton and adult fish data were collected using port samplers in the United States and Mexico, and five research vessels operating between San Ignacio Lagoon (Mexico) and San Francisco (California). The DEP estimate for 1994 used in the biomass estimate was 126,000 t according to Statistician C.H. Lo (CV=46 percent).

CDFG used a Catch at Age Analysis for Sardine (CANSAR) stock assessment model using DEP data, indices of abundance based on fish spotter and CalCOFI data (provided by the Southwest Fisheries Science Center), an index based on spawning area, U.S. and Mexican fishery data, and Scripps Pier Temperature records. CANSAR was derived from the CAGEAN program by Richard Deriso (Scripps Institution of Oceanography) with modifications to accommodate fishery independent abundance indices, DEP spawning biomass estimates, landings data without catch-at-age information, and environmental effects on recruitment.

Scientists concluded that sardine biomass increased from very low levels in 1983 to approximately 330,000 t in 1994 (Fig. 3). The quota for California fishers during 1995 was set by CDFG at 15 percent of the total biomass estimate or approximately 50,000 t. If the entire quota is taken, sardines will likely be the first or second most important species in California in terms of landings and among the top ten in terms of exvessel revenues. During 1993, Pacific sardine was the second most important species landed in terms of total landings and, including live and dead bait, the thirteenth most important in terms of exvessel revenue. (J. T. Barnes, 619-546-7167, and L. D. Jacobson, 619-546-7117)

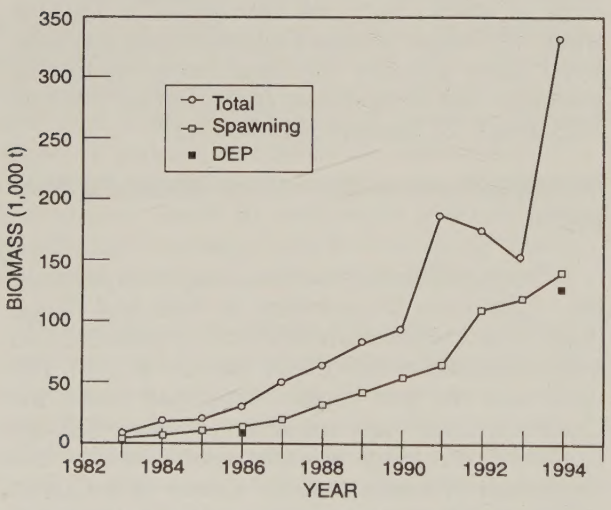

Figure 3. Total (ages 1+ on July 1) and spawning (on March 1) biomass during 1983-1994, and daily egg production (DEP) estimates of spawning biomass for 1986 and 1994 from the Catch at Age Analysis for Sardine model.

HONOLULU LABORATORY

Honolulu, Hawaii

PROTECTED SPECIES INVESTIGATION

Preliminary Results of 1994 Hawaiian Monk Seal Field Studies

During 1994, field studies of the endangered Hawaiian monk seal were conducted at four of its six main reproductive sites, including French Frigate Shoals (FFS), Laysan Island, Kure Atoll, and Midway Atoll. Field effort on Lisianski Island was limited to a single day and no studies were conducted at Pearl and Hermes Reef. The two principal indices of the status of this endangered species are the number of pups born and the sum of the mean beach counts at the main reproductive sites; neither index could be completed due to the lack of effort at Pearl and Hermes Reef and Lisianski Island. Nevertheless, information from FFS, in particular, indicates that severe problems persist. Survival of immature animals continues to be extremely poor; at FFS, less than 30 percent of the 1993 cohort survived their first year. The continued poor survival at this and several other sites has severely distorted the age distribution and, in the near future, reproduction is expected to decline due to a drop in recruitment.

To salvage some female pups (and the reproductive potential they represent), eight undersized seals were removed from the FFS population and transported to Oahu for rehabilitation and eventual return to the wild. One of those pups died in captivity, but the remaining seven are healthy and gaining weight and should be ready for release at Kure Atoll by next spring.

In addition to the rehabilitation program, a second major management effort was directed at the Laysan population. Twenty-two adult males were removed from this population to normalize the adult sex ratio and mitigate the occurrence and

effect of mobbing. The males were released around the main Hawaiian Islands and are being monitored by cooperating biologists on neighbor islands and by ARGOS satellites; five males were instrumented with satellite transmitters. The releases occurred in late July and early August and, as of late November, the males generally have remained near the sites where they were released.

Finally, monitoring efforts by the Marine Mammal Research Program were significantly enhanced this year through contributions by L. Eberhardt and K. Eberhardt, cooperating scientists. In March, the Eberhardts visited Midway Atoll, where they photographed and filmed the resident population of seals. The resulting records provide our best documentation of this population in recent years. The efforts at Midway and other locations are summarized below.

French Frigate Shoals. Field studies were conducted from February 6 to 17 under the direction of Fishery Biologist John Henderson, and from March 29 to September 17 under the direction of Mitchell Craig, cooperating scientist. In February, effort focused on evaluating seals born in 1993 to determine if any were in need of rehabilitation and on retrieving of satellite transmitters from three subadult males instrumented in September 1993. Of 78 weaned pups tagged in 1993, only 12 (4 female, 8 male) were sighted in February 1994; of those, all were larger than the predetermined collection criterion, and none were taken into captivity. All three satellite transmitters were successfully retrieved. Preliminary results from one seal indicate a foraging pattern not seen before in Hawaiian monk seals (see accompanying article in this report, pg. 7). The seal exhibited foraging cycles of 2-3 weeks at sea (approximately 50-100 km northeast of FFS, interspersed with resting periods of 3-4 days at the atoll). The diving record indicates that the seal dived to at least 500 m (the limit of the time-depth recorder the seal was carrying).

Field studies during the remainder of the season focused on (1) atoll counts of seals, (2) sighting efforts for estimating survival rates, (3) determination of number of pups born, (4) evaluation of seal condition, (5) collection of undersized weaned pups for rehabilitation, (6) detection of evidence of fisheries interactions, and (7) assessment of injuries and deaths due to shark attacks, adult male aggression, or entanglement in marine debris. The mean (± standard deviation) of 10 atoll counts (excluding pups) was 158.1 (±15.1), approximately the same as in 1993. Annual survival rates for the past year were approximately 50 percent or less for the youngest four age classes. Survival was particularly poor for the 1993 cohort; of 38 females tagged, 11 were removed for rehabilitation, and 9 of the remaining 27 were sighted 1 year after birth.

One hundred and nine pups were born at FFS; 90 were tagged (43 female, 47 male), 5 were still nursing at the end of the season (and therefore were not tagged), and 14 either disappeared or died (4 of which were known to have large shark-inflicted wounds). Three of the adult females giving birth had traveled from Laysan Island to pup at FFS.

A total of 17 seals were found with gaping wounds or amputations caused by sharks. One adult female had multiple punctures and abrasions on 50 percent of her back (indicating that she had been mobbed), and another adult female had an old mobbing wound reinjured by mating attempts. Three pups were found with large dorsal abscesses that probably resulted from bites by adult males. One adult female had a large fishing hook embedded in her mouth, which was not removed because she appeared to be pregnant.

Laysan Island. Field studies were conducted from March 23 to August 2 under the direction of H. Johnston, cooperating scientist, and William Gilmartin, leader, Marine Mammal Research Program. The mean (± standard deviation) of 20 beach counts (excluding pups) was 74.4 (±8.8), which is similar to the past three years. The total number of animals in the population (excluding pups) was 220, 14 more than counted in 1993, but the difference appeared to be due largely to Laysan animals that had not been observed in 1993. The population included 82 adult males and 69 adult females (approximately 1.2:1.0). At the end of the field season, 22 adult males were captured for translocation from Laysan Island to the main Hawaiian Islands, reducing the sex ratio to approximately 0.9:1.0.

The birth rate was 71 percent for adult-sized females. Forty-nine pups were born (29 female, 19 male, 1 unknown), the highest number recorded since 1977. Forty-seven were tagged after weaning; the remaining two died prior to weaning. A total of six seals were known to have died, and two others disappeared and are assumed to have died. Two deaths and one disappearance (two adult females and one juvenile male) were attributed to mobbing, an adult of unknown sex disappeared after receiving a shark-inflicted injury, an adult male died during capture for the translocation, and three pups (a

weaned male and two neonates—one male and one of unknown sex) died of undetermined causes. A nonfatal mobbing event was observed which involved an adult female and six adult males. Three seals were entangled in marine debris and were released uninjured by observers. All marine debris capable of entangling an animal was inventoried and destroyed. Of 17 seals that had been oiled from a spill in 1993, 16 were sighted in 1994.

Lisianski Island. John Henderson led a 1-day effort (July 20) on Lisianski Island to resight previously tagged seals and to tag weaned pups. Seven weaned pups were tagged with Temple Tags and Passive Integrated Transponders (PITs). Three additional pups were sighted but could not be tagged; minimum pup production for 1994 was, therefore, 10 animals. One weaned pup was entangled about the neck by a fragment of polypropylene net and was released uninjured. Approximately 50 percent of the debris capable of entangling wildlife was gathered and burned, but the remaining debris could not be destroyed because of the short visit.

Midway Atoll. L. and K. Eberhardt conducted field studies at Midway Atoll from March 5 to 31. Due to difficulty with transportation around the atoll, whole atoll counts were not conducted according to the standard protocol. Instead, beach counts were conducted separately for each island, and the combined averages totaled 12.7 seals (excluding nursing pups). Based on a combination of bleach marks and tags, 29 different individuals were identified, 4 of which were pups. On the basis of probability calculations, scientists suggest that they found all, or nearly all, seals using the site in March, and the total population probably consisted of 30-35 seals. The majority of the population are either immigrants from other locations or offspring of those immigrants.

Kure Atoll. Mitchell Craig directed field studies of the Hawaiian monk seal at Kure Atoll from February 11 to March 25. The primary purpose of the camp was to determine the composition of the population (excluding pups), thereby providing information necessary to evaluate the survival of seals released at Kure to enhance the recovery of this population. In addition, all marine debris capable of entangling seals was collected and destroyed.

Eight atoll counts were conducted, and the mean (± standard deviation) count (excluding pups) was 57.8 (±6.3) seals. However, these counts were conducted at a different time of year and, because monk seal hauling patterns are known to vary by season, the 1994 counts are not reliably comparable to counts in previous years. A total of 112 seals were identified: 43 adults, 28 subadults, and 41 juveniles. These numbers probably include all or nearly all nonpup seals at the atoll. Six pups had been born by the end of the field studies, but additional births were expected. One pup was apparently washed offshore during a high tide and was not seen again.

Eight yearling seals were transported to Kure on the NOAA ship *Townsend Cromwell*. These seals were from FFS, and had been rehabilitated on Oahu. Six were released on February 11 and two were released on March 25. Of 14 yearlings that had been released at Kure in 1993, 11 were resighted in 1994 (9 at Kure Atoll and 2 at Midway Atoll). One adult seal was found dead. The death probably occurred in 1994, but the carcass was too deteriorated to determine cause of death. (T. Ragen, 808-943-1280)

Pelagic Foraging of an Hawaiian Monk Seal

Our current understanding of the natural history of the Hawaiian monk seal is based almost entirely on its behavior on land; we know very little of behavior at sea. The available evidence on foraging patterns comes largely from analysis of prey items in scats, spews, and (occasionally) stomach contents of dead animals. The data suggest that monk seals are opportunistic feeders preying on a variety of reef and benthic fishes, as well as octopus, squid, and lobster. These results are biased toward prey items containing hard tissues that pass through the digestive tract and items that are eaten close to shore and therefore more likely to be eliminated or regurgitated onshore, where they can be collected for analysis.

In addition to scats and spews, we have five other (albeit limited) sources of information pertaining to monk seal foraging patterns:

(1) Sightings at sea indicate at least some use of the areas where sightings occur (that is, Maro Reef, which is thought to be an important foraging area). However, sightings are incidental, infrequent, and dependent on the spatial/temporal distribution of sighting effort. The pelagic areas around the Northwestern Hawaiian Islands have not been systematically surveyed, and the total number of seals is so small that such surveys would probably provide very little information.

(2) Sightings on land confirm that seals undertake long-range movements (between islands or atolls). Seals are also seen periodically in the main Hawaiian Islands and, on rare occasions, have been seen at Johnston Atoll, almost 1000 km south of the Northwestern Hawaiian Islands, and Palmyra Atoll, over 1800 km south of Nihoa Island. The majority of seals, however, show a high degree of fidelity to their natal island/atoll.

(3) Estimates of maximum swimming speed, combined with hauling records at a particular island, can be used to infer limits on the distances traveled during foraging bouts. However, hauling records indicate that some individuals may be away from an island for weeks or even months, and the limits cannot be estimated accurately from such long absences.

(4) Diving patterns have been studied using time-depth recorders. In earlier studies, the aim was to identify critical habitat. However, use of the collected records to infer diving location assumes that seals are diving to the bottom, which was not verified. In general, the results from time-depth studies suggest that Hawaiian monk seals are not deep divers. The maximum depth recorded in these studies was approximately 280 m, but the vast majority of dives were less than 100 m.

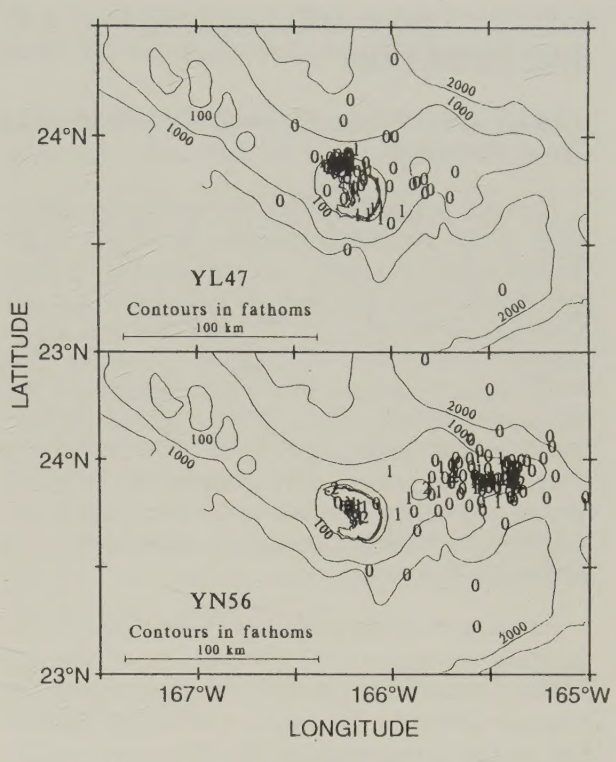

Figure 1. Satellite locations of two subadult Hawaiian monk seal males from French Frigate Shoals. Seal YL47 (top) foraged primarily near the atoll. Seal YN56 (bottom) demonstrated a pelagic foraging pattern. 1, 2 = reliable locations; 0 = unknown reliability.

(5) Satellite-linked time-depth recorders provide a combination of diving patterns and geographic location. In 1992, recorders were attached to three subadult males at FFS. The results were consistent with previous notions about the foraging patterns of monk seals: the majority of dives were shallow (≤100 m) and most of the diving activity occurred around the atoll (Fig. 1, top). Some of the location records suggested that these seals may have ventured out over deeper water, but virtually all records over deep water were of unknown reliability (that is, the satellite provided an estimate of location but could not provide a measure of confidence in the estimate).

In 1993, three more subadult males were instrumented with transmitters, and two of the males appeared to forage in much the same manner as the males in 1992; their dives were relatively shallow and they stayed in the vicinity of FFS. The third male, however, illustrated a foraging pattern unlike any previously seen for Hawaiian monk seals. This animal alternated 2- to 3-week foraging bouts with 3- to 4-day rest periods on land. Virtually all of its diving activity occurred approximately 50 to 100 km northeast of the atoll (Fig. 1, bottom), over waters between 200 and 2000 m deep. This male also dove deeper than any other males in the previous records, with a diving mode at 400 m and a number of dives at the maximum limit of the recording instrument (500 m).

The extent of pelagic foraging among other monk seals is, as yet, undetermined. Nevertheless, the records from this animal provide the first incontrovertible evidence of such foraging and, therefore, provide important impetus to focus attention and effort on investigation of foraging patterns. Such investigation is critical to our understanding of their population dynamics (such as the ongoing decline at FFS), to our assessment of direct and indirect fisheries interactions, to our determination of critical habitat, and to our understanding of the relationship of this endangered species with its environment. (T. Ragen, 808-943-1280)

FISH BIOLOGY AND ECOLOGY INVESTIGATION

Hawaii Swordfish Fishery Oceanography Grant Awarded

A major requirement for improving the assessment of the swordfish resource exploited by the Hawaii longline fishery is to evaluate the environmental influences affecting the availability and vulnerability of the resource. Toward this end, a new research project was initiated in December 1994 with funding provided by the Joint Institute of Marine & Atmospheric Research (JIMAR) Pelagic Fishery Research Program (PFRP) at the University of Hawaii. The project will incorporate remotely sensed and in situ environmental information into a fishery performance model for swordfish in the central North Pacific.

Initial goals of the project are to (1) examine and quantify environmental features, especially sea-surface temperature gradients, that are expected to be important to the dynamics of swordfish distribution and gear vulnerability and (2) improve interpretation of swordfish catch-per-unit-effort data used by the Western Pacific Regional Fishery Management Council in evaluating management alternatives for the domestic longline fishery. Several other cooperating PFRP projects will investigate sea level variation, ocean color, and circulation patterns that may be relevant to swordfish distribution and vulnerability. Once relevant features are identified and quantified at the appropriate scale, these factors will be incorporated into comprehensive swordfish fishery dynamics models. (C. Boggs, 808-943-1222)

FISHERY MANAGEMENT & PERFORMANCE INVESTIGATION

Hawaii's Longline Fishery, 1993

During 1993, 122 longline vessels active in Hawaii completed 1,233 trips. The number of trips completed declined by about 5 percent compared to 1992, whereas the number of hooks set increased by over 10 percent to 13.2 million. The number of sets completed (days fished) increased by about 7 percent in 1993 compared to 1992. Since the beginning of 1994, 117 vessels have been active although several swordfish longliners have returned to the mainland and other Hawaii longline vessels have moved to Fiji.

Broadbill swordfish, *Xiphias gladius*, continued to be the largest component of the landings in 1993 (N = 75,700), followed by bigeye tuna, *Thunnus obesus* (N = 53,600), and mahimahi, *Coryphaena hippurus* (N = 24,500). The total number of swordfish caught and retained comprised almost 30 percent of the total number of fish landed (N = 256,400). Landings for bigeye and yellowfin, *T. albacares*, tunas increased throughout the year and comprised 21 percent and 6 percent, respectively, of the total 1993 landings. The number of sharks reported caught in 1993 jumped by almost 39 percent over 1992 and accounted for the largest component of the longline catch (N = 154,600), but relatively few were landed (N = 16,700). Blue sharks, *Prionace glauca*, were by far the most abundant species of shark caught (N = 150,000+) and represented over 36 percent of the total catch for 1993, compared to a combined catch of about 1 percent for shortfin mako, *Isurus oxyrinchus*; bigeye thresher, *Alopias superciliosus*; and miscellaneous sharks including oceanic white tip, *Carcharhinus longimanus*, and silky, *C. falciformis*, during the same period.

More shark fins were landed in 1993 than any previous year during the moratorium, and there was more than a fourfold increase in the number of sharks reported kept compared to 1992. According to longline logbook data for 1993, over 14,300 blue sharks were reported kept (that is, finned). Using average whole weights of blue sharks from longline observer data (Fishery Management and Economics Program, unpublished records) collected during 1990-91 (N = 450), the total whole weight of blue sharks finned by the Hawaii longline fleet during 1993 was estimated to be around 612,360 kg (1.35 million pounds).

In 1993, approximately 43 percent of the domestic longline fishing effort was within the 200-mile Exclusive Economic Zone (EEZ) of the main Hawaiian Islands, where bigeye tuna made up the largest portion of the landings. About 10 percent of the fishing effort was within the 200-mile EEZ of the Northwestern Hawaiian Islands, where broadbill swordfish constituted the largest portion of the landings and almost half of the effort was outside Hawaii's EEZ, with most landings also being swordfish. Through the current period in 1994, fishing effort has been more concentrated inside the Hawaii EEZ, with tunas being the primary target.

Preliminary average sampling weights from dockside and wholesale market monitoring in Honolulu suggest that landings of swordfish in 1993 increased to approximately 6 million kg (13 million pounds, round weight) with an ex-vessel

revenue of $26.6 million. Landings of bigeye tuna (2.2 million kg [4.8 million pounds] worth $17.2 million) increased over 1992, while landings of yellowfin tuna (680,400 kg [1.5 million pounds] worth $4.1 million) increased significantly (NMFS unpublished records).

Catch-Per-Unit Effort (CPUE) -- CPUE (number caught per 1,000 hooks) for billfish declined by 3 percent in 1993 with swordfish down by 4 percent. Bigeye, yellowfin and albacore (*T. alalunga*) tuna CPUE all increased (11, 46, and 41 percent, respectively), while mahimahi CPUE declined dramatically (59 percent). CPUE for sharks rose by 32 percent.

Interactions with Endangered and Protected Species -- Federal observers began embarking on Hawaii-based longline vessels on a voluntary basis during the last quarter of 1993. An interim final rule issued by the Secretary of Commerce required all permit holders of Hawaii-based longline vessels to accommodate observers on a mandatory basis beginning in 1994. In addition, an electronic vessel monitoring system will be implemented. The observer requirement was deemed necessary by the NMFS to ensure adequate reporting of interactions between longline fishing gear and sea turtles. Hawaii longline logbook data and volunteer observer data prior to January 1994 indicated that guidelines for turtle interactions or "take" had been exceeded under the original Biological Opinion. The conservation of sea turtles is of particular concern, and as a result, NMFS, Southwest Region included a conservation recommendation that the Fishery Management Plan be amended to prevent increases in longline effort until it is demonstrated that turtle interactions are being managed at a level that will allow recovery of the species.

During calendar year 1993, Hawaii-based longline vessels reported in their logbooks a total of 264 interactions with endangered and protected marine species. Interaction data from logbooks submitted to NMFS indicated that 67 percent of the interactions were with seabirds, 30 percent with marine turtles, and 3 percent with whales or dolphins.

All interactions with protected species were reported as number of animals released alive, injured, or dead, since it is unlawful to retain protected species. Logbook interactions data showed that 54 percent of the animals were released alive, 3 percent were released injured, and 43 percent were released dead (3 green turtles, *Chelonia mydas*, 1 leatherback turtle, *Dermochelys coricea*, and 110 birds).

Over 69 percent of the interactions reportedly occurred outside the U.S. EEZ. The rate of interaction for turtles was calculated at 0.12 per 100,000 hooks inside the EEZ and 1.15 turtles per 100,000 hooks set outside. The number of reported interactions overall increased 32 percent from the previous year as a result of an increase in fishing effort during 1993. Although the amount of effort within the EEZ during 1993 increased, turtle interactions declined. Outside the EEZ, however, turtle interaction rates increased, although fishing effort was approximately the same as in 1992.

A more detailed assessment of the 1993 longline fishery is available in Administrative Report H-94-06. (R. Dollar, 808-943-1210)

Northwestern Hawaiian Islands Bottomfish Fishery, 1993

During 1993, Federally managed Northwestern Hawaiian Islands (NWHI) bottomfish landings of 175,000 kg (385,000 pounds) fell short of 1992's high of 192,000 kg (424,000 pounds). Overall effort in terms of number of trips, however, rose from 92 to 106. The number of vessels fishing decreased from 13 to 12.

Although most of the fishing activity has usually centered around those islands nearer the main Hawaiian Islands, the permitted vessels fishing the limited-entry Ho'omalu zone have been ranging farther up the Hawaiian Archipelago. This is the third time since the early 1980s that longer-range fishing trips have been used to locate concentrations of bottomfish.

Landings of opakapaka, *Pristipomoides filamentosus*, which have increased for the last 4 years, continue to dominate the landings. Onaga, *Etelis coruscans*, landings nearly doubled, while the strong 3-year run of uku, *Aprion virescens*, is on the decline and has dwindled to less than half of the 1992 landings. Landings of other species have fluctuated somewhat.

A detailed assessment of the 1993 bottomfish fishery has been issued by the Honolulu Laboratory as Administrative Report H-94-07. (K. Kawamoto, 808-943-1213)

PACIFIC FISHERIES ENVIRONMENTAL GROUP

Monterey, California

Rockfish Refuges In Deep Water Canyons

A team of marine biologists and geologists successfully completed the second year of field research to evaluate the function of deep water submarine canyons in the Monterey Bay area as natural refuges from fishing for several species of bottom-dwelling rockfishes, *Sebastes* spp. Led by Pacific Fisheries Environmental Group's (PFEG) Fishery Biologist Mary Yoklavich, the team comprises scientists from PFEG, Moss Landing Marine Laboratories, California Department of Fish and Game, U.C. Santa Barbara, and the Sea Grant Marine Advisory Program. Their study has been supported by grants from NOAA's National Undersea Research Center in Fairbanks, Alaska.

During 1993, commercial fishermen landed nearly 8.6 million kg (19 million pounds) of rockfish at California ports at a value of more than $9 million. During the same period, recreational anglers caught an estimated 1.8 million kg (4 million pounds) of rockfish off California. However, smaller sizes and lower numbers of some rockfish species have increased management concern, leading to recent recommendations by the Pacific Fishery Management Council regarding management of the inshore rockfish complex. Considering these trends, our study focuses on comparisons of rockfish assemblages and their associated habitats among several areas that receive varying amounts of fishing pressure throughout the Monterey submarine canyon system.

As the name implies, most rockfishes are associated closely with rocky habitats, which are difficult to survey using traditional sampling gear such as trawls. Instead, we successfully used the small, manned *Delta* submersible to characterize habitats that support adult rockfishes in deep water, and to compare abundance, sizes, and fine-scale distribution and habitat specificity (type and depth) for rockfishes at both lightly- and heavily-fished rocky sites. From September 19 to 27, 1994, researchers made 45 scientific dives (almost 70 hours underwater): 15 dives each in Ascension and Carmel Canyons, 4 dives in Ano Nuevo Canyon, and 11 dives at two sites along the Big Sur coast of central California (Fig. 1). Depth of most dives ranged from 90 to 300 m. Nine dives were dedicated to geologic observations and large-scale description of habitat;

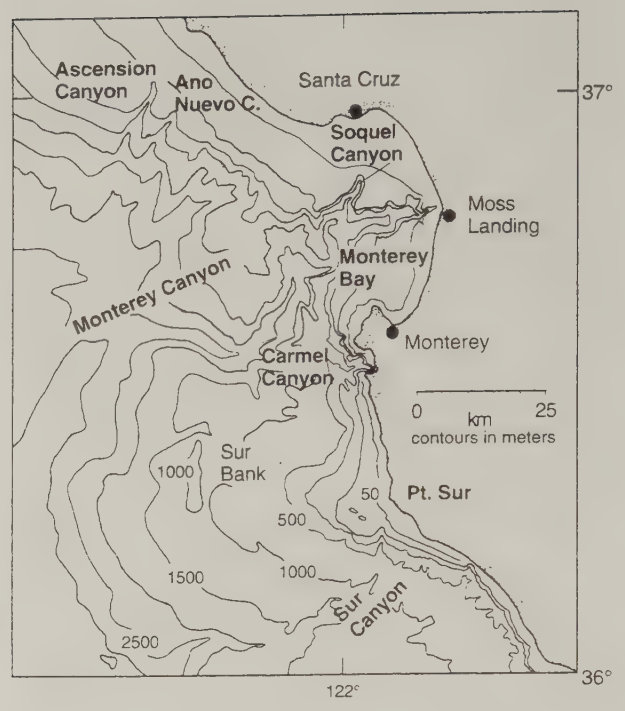

Figure 1. General locations of 1994 submersible study sites in Ascension, Ano Nuevo, and Carmel Canyons, and off Pt. Sur.

36 dives were made by 8 experienced fishery biologists. Dives were documented continuously with an externally-mounted HI-8–mm video camera, and verbally annotated by the observer. Two parallel lasers, one on either side of the camera, were critical in estimating fish size and the distance fish traveled during quantitative video transects (Fig. 2).

From preliminary analysis of 72 15-min video transects, scientists observed 25,636 individual fishes from at least 66 species, including 20,998 rockfishes from at least 30 species. Rockfish species richness was highest at sites with extensive and complex rock habitat (that is, boulders and cobble fields, crevices, ledges, and overhangs), including Carmel Canyon (27 rockfish species) and Pt. Sur (20 rockfish species). Rockfishes, in general, were the most abundant group, ranging from 64 percent (Ano Nuevo Canyon) to 96 percent (Pt. Sur) of total number of fishes.

Fish assemblages will be compared between areas that receive less fishing pressure (Soquel Canyon sites surveyed in 1992-93; Pt. Sur) and those that have been fished heavily and continuously for several years (parts of Soquel, Monterey, Carmel, Ascension, and Ano Nuevo Canyons; and Portuguese Ledge). Large schools of uniden-

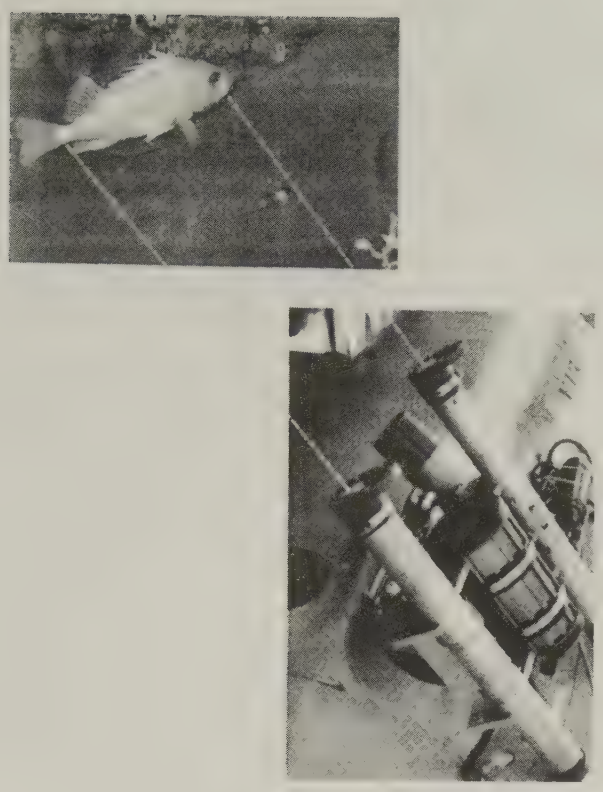

Figure 2. Composite demonstrating (a) the parallel lasers mounted to an underwater camera and used to estimate fish size and distance traveled along transects, and (b) an in situ video print of a green-spotted rockfish, *Sebastes chlorostictus*, at interface of boulder and mud substratum.

tified young-of-the-year rockfishes (YOY) and adults of small semi-pelagic species (for example, pygmy, *Sebastes wilsoni*; squarespot, *S. hopkinsi*; and halfbanded, *S. semicinctus*) dominated shallow (90-120 m) rock areas of low relief outside the submarine canyons in both fished and less-fished areas; large schools of YOY rockfishes were almost absent at any depth within the canyons. Although appropriate habitat was available in areas of heavy fishing pressure, initial impressions of these areas suggest that there are fewer individuals of large species. These species were of smaller size composition and perhaps varying species composition. Researchers also documented a surprisingly high incidence of discarded fishing gear (for example, trawl nets, gillnets, lines, and traps) in some canyon sites; as many as seven large nets were observed during one 15-minute transect in Ascension Canyon. Analyses of the video transects and resultant data continue.

From preliminary results of a study in various submarine canyons, the adult rockfish assemblages in relatively unfished heterogeneous, rocky habitat that is surrounded by soft mud in the deep waters of Soquel Canyon appear to be different in terms of abundance, size, and species composition. This information suggests that assemblages of large species of rockfishes (for example, *Sebastes ruberrimus, S. levis, S. chlorostictus, S. rosenblatti*) associated with deep isolated outcrops on steep slopes are likely protected from excessive harvest because habitat characteristics make them difficult to target. The results will be useful in evaluating the benefits of establishing marine harvest reserves, resource assessment and management of the Monterey Bay National Marine Sanctuary, ground-truthing the results of remote sensing surveys (for instance, using side scan sonar), as well as understanding associations between economically important fish assemblages and their habitat in areas that have been difficult to evaluate using traditional methods. (M. Yoklavich, 408-648-9036)

IT-95 Progress at PFEG

The IT-95 server for Monterey has been ordered and delivery is set for mid-January 1995. The Control Data 9460 server, which was selected for all IT-95 sites, provides a powerful distributed computing environment for generating, managing and storing data. The CDC 9460 contains two central processors and can be expanded to as many as 12 central processors. The Monterey server uses two 150-MHz MIPS RISC microprocessors. It will be delivered with 128 megabytes of memory.

A plan was developed to designate the Monterey host as the server for the Tiburon Laboratory. Software was chosen during the configuration process that would meet the needs of the Tiburon and PFEG staff. SAS, a statistical analysis software package which is not used at PFEG, was ordered for the server, in light of the usage of SAS at Tiburon. When Tiburon's local area network (LAN) is in place, researchers there will access the server through the NMFS wide area network (WAN). Users will connect to the server as if they were accessing a local workstation. The data circuit for the NMFS WAN has been installed at PFEG, and the router, a NetBuilder 227, has been delivered.

The latest version of Oracle—Version 7.1.3—has been installed on PFEG's IT-95 Silicon Graphic Indigo 2 workstation. This version corrects several problems that plagued the previous version. As a preliminary test, PFEG's monthly upwelling index has been placed in an Oracle database. Communi-

cations software to provide connectivity to the UNIX host for the PFEG Macintosh environment was surveyed. A program that provides full X-windows connectivity, eXodus for MacIntosh, was chosen for further evaluation and is currently being tested.

PFEG's IT-95 liaison, Computer Specialist Paula Mercer, attended the IT-95 System Administrator's Workshop at the NOAA Western Regional Center in Seattle October 25-27. In addition to exchanging technical information, workshop participants formulated and recommended standards to be adopted by all IT-95 sites. Several committees were formed to further investigate issues raised at the workshop and to continue the intersite communication process begun at the workshop. Mercer was appointed to the Oracle CASE/Application Development Tool Committee and the Oracle Naming Conventions and Standardization Committee.

In November, Mercer attended an Oracle Database Administration class that dealt with such issues as auditing and monitoring database activity, tuning the database, and advanced backup and recovery techniques. (J. Steger, 408-648-9035)

PELAGIC FISHERIES RESOURCES DIVISION

La Jolla, California

STOCK ASSESSMENT AND FISHERY IMPACT ANALYSIS PROGRAM

High-Seas North Pacific Albacore Observer Program—1994

Since 1990, the SWFSC has placed scientific observers on cooperative U.S. albacore troll vessels operating in the North Pacific. This effort produces catch, effort, and length frequency data and information on fishery interaction. During the 1994 season, four observers collected fishery data during a total of 252 fishing days on four trips. More than 150 metric tons (t) of albacore were landed during these trips, and 10,701 albacore were measured and examined for evidence of encounters with other types of fishing gear. Only 1 percent of the 10,701 albacore examined showed indication of damage. Of these, about 11 percent appeared to have occurred during the current fishing season.

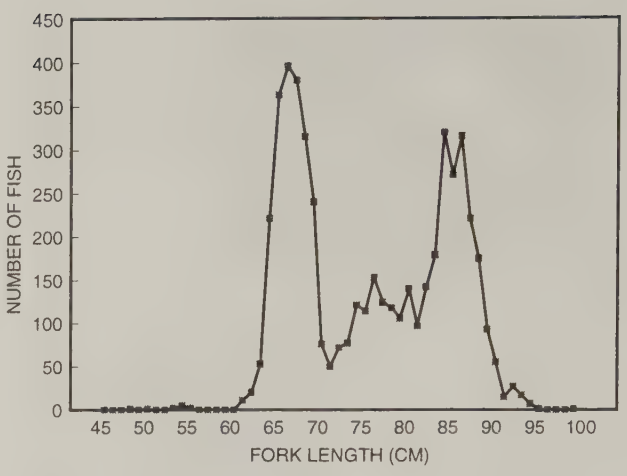

Figure 1. Length frequency of albacore caught east of the International Date Line.

This season marks the first time vessels with observers traveled west as far as 173° E near the Emperor Sea Mounts. Catches there were very good and at times exceeded 1,000 fish per day. Albacore taken averaged 75 cm fork length (FL) and fell into three size groups. Albacore caught east of the International Date Line consisted of the same three sizes, but had a lower percentage of large fish (Fig. 1). These albacore averaged 69 cm FL overall. As the fleet continued east from the mid-Pacific, fishing went well with many 6 to 7 kg (14 to 16 pound) fish caught. Coastal vessels also reported good fishing within 100 nautical miles of the North American coast.

U.S. albacore fleet catch from 1977 to 1993 averaged 6,300 t but has not exceeded 5,000 t since 1985. The catch for the 1994 season exceeded 10,000 t for the first time in over a decade. The good catches and large fish found west of the International Date Line encouraged fishermen—many of whom plan to fish the Emperor Sea Mount area early in the 1995 season. (D. Holts, 619-546-7186)

Abundance Indexing for Pelagic Sharks

A cooperative experiment to develop and evaluate a catch-per-unit-effort index for pelagic sharks (shortfin mako, *Isurus oxyrinchus*; common thresher *Alopias vulpinus*; and blue sharks, *Prionace glauca*) in the waters off southern California is being conducted by Southwest Fisheries Science Center's PFRD and the California Department of Fish and Game (CDFG). The research is being conducted because of limited data from which catch and effort indices can be used to determine relative abundance.

Commercial landings of the three primary pelagic shark species by the driftnet fishery and the mako shark longline fishery (now terminated) have decreased substantially from highs in the mid- to late-1980s. Changing goals and an increasing number of regulations governing these fisheries have resulted in wide swings in distribution of fishing effort and catch sizes. This in turn has hampered attempts to determine abundance. The aim of this research is to provide a reliable index of shark abundance in the southern California bight.

Three cruises were completed in 1994, the last one ending in October 1994. The first and third cruises were conducted aboard the CDFG research vessel *Mako*, and the second cruise was conducted aboard the NOAA vessel *David Starr Jordan*. Scientists used stainless steel longline gear and techniques developed in the 1993 field season. The length of the longline and duration of each set varied between cruises depending on location, weather, and operational constraints. All sets were conducted during daylight hours. Overall catch was consistent with CDFG catch statistics.

The three cruises logged a total of 47 fishing sets in 31 days within the Southern California Bight (Table 1). During the research period, 6,094 hooks were deployed. Catch totaled 432 blue sharks, 1 common thresher shark, 215 shortfin mako sharks, and 114 pelagic rays. Catches varied between 0 to 7.0 mako sharks per 100 hooks. Although final analysis is pending, the proportion of catch of mako sharks was considered consistent with previous data.

Table 1. Summary of 1994 cruise results.

Research Cruise	*Mako*	*David Starr Jordan*	*Mako*
Dates	June 13-17	July 11-24	Oct. 17-28
Days	5	14	12
Fishing sets	4	22	21
Total hooks	360	3,649	2,085
Catch			
Mako	3	148	64
Blue	4	121	307
Thresher	0	1	0
Pelagic ray	0	114	-
Sharks/100 Hooks	0.8	7.4	17.4
Mako/100	0.4	4.1	3.2
Mako highest	0.5	6.9	7.0
Blue/100	1.2	3.3	14.2
Sharks tagged			
Mako	3	92	54
Blue	4	111	284
Thresher	0	1	0

All fish healthy when caught were tagged with CDFG spaghetti tags and released. Tagged and released fish totaled 1 common thresher shark, 149 shortfin mako sharks, and 399 blue sharks.

In addition to cruise objectives, several "piggy back" projects were supported by the PFRD. Lai Chin and Keith Kobsmyer (Scripps Institution of Oceanography) measured blood gas properties, blood flow, and vascular pressures on 11 shortfin mako sharks. John O'Sullivan of the Monterey Bay Aquarium participated on the *David Starr Jordan* cruise and successfully collected 14 pelagic stingrays, *Dasyatis violaecea*, for display. Rockfish samples were collected routinely for mtDNA analysis for the Coastal Division. Sixteen grade school students sponsored by the Outreach Project from the Los Angeles area participated in a 1-day trip aboard the research vessel *Mako*.

PFRD staff who participated in the cruises included Norm Bartoo, John Childers, Dave Holts, Darlene Ramon, and Rand Rasmussen. CDFG biologists included Mary Larson, Leanne Laughlin, Bob Reed, and Marija Vojkovich. (D. Holts, 619-546-7186)

International Symposium on Pacific Swordfish Held in December

An International Symposium on Pacific Swordfish was held December 11 to 14, 1994, in Ensenada, Mexico. The event was hosted by CICESE (the graduate University in Ensenada). SWFSC scientists assisted in organizing the event as members of the steering committee.

The objective of the symposium was to provide a forum on the recent development of fisheries, market trends, and biological research on swordfish, and to promote international scientific collaboration. The scope was limited to Pacific swordfish with only a few exceptions. Over 25 papers that were presented will be peer-reviewed and published in a single volume. The audience was open to anyone; considerable interest was shown by scientists, commercial interest groups, and government administrators. The symposium was attended by more than 70 participants from 6 countries around the Pacific Rim. (N. Bartoo, 619-546-7003)

MULTISPECIES DATA COLLECTION AND EVALUATION PROGRAM

Seychelles Purse Seine Data Updated

Fishery Biologist Alan Jackson updated the second quarter 1994 Seychelles Fishing Authority data on the tuna purse seine fishery in the western Indian Ocean. The data are summarized in LOTUS spreadsheets and cover the period 1983 to the present.

The number of vessels participating monthly in the purse seine fishery in the western Indian Ocean during the second quarter of 1994 averaged 34 (16 Spanish, 15 French, 2 Mauritian, and 1 Panamanian)—a considerable decrease from the average 51 vessels recorded for the same period the previous year. This is largely due to the disappearance of the Japanese fleet. The number of Japanese purse seiners declined from January 11 to December 1, 1993. No Japanese seiners have participated in this fishery since January 1994. The monthly average number of vessels participating during the first two quarters of 1994 was 38—down 27 percent from the previous year. The number of vessel days fished in the second quarter of 1994 was 2,442—down 31 percent from the previous year. The number of vessel days fished for the first two quarters of 1994 was 5,281—down 30 percent.

Purse seine catches of skipjack tuna, yellowfin tuna, and other tunas in the western Indian Ocean in the second quarter of 1994 totaled 49,400 t—down 19 percent from the previous year. The species breakdown of the catch is 66 percent skipjack tuna, 24 percent yellowfin tuna, and 10 percent other tunas. For the first two quarters of 1994, the catches totaled 124,700 t—down 6 percent—and were composed of 42 percent skipjack tuna, 48 percent yellowfin tuna, and 10 percent other tunas (Fig. 2).

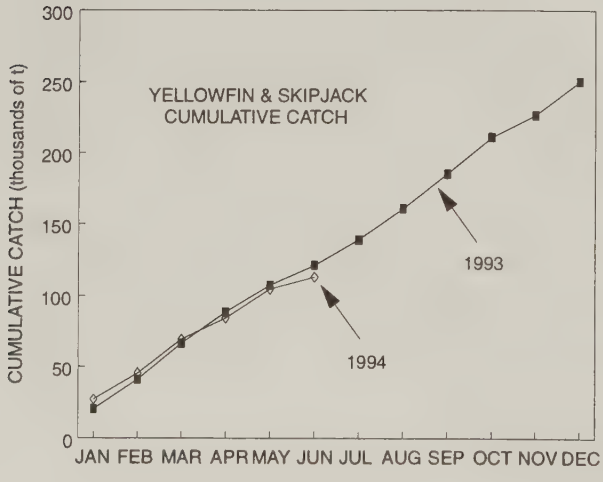

Figure 2. Cumulative catches (metric tons) of yellowfin tuna and skipjack tuna by purse seiners in the western Indian Ocean, 1993-94.

The catch rate for all tuna species for the second quarter of 1994 was 20 t per vessel day—up 18 percent from the previous year. Catch rates for skipjack and yellowfin tunas were 13 and 5 t per vessel day, respectively. For the first two quarters of 1994, the catch rate for all tunas was 24 t per vessel day—up 33 percent—with skipjack tuna and yellowfin tuna catch rates of 10 and 11 t per vessel-day, respectively (Fig. 3). (A. Jackson, 619-546-7048)

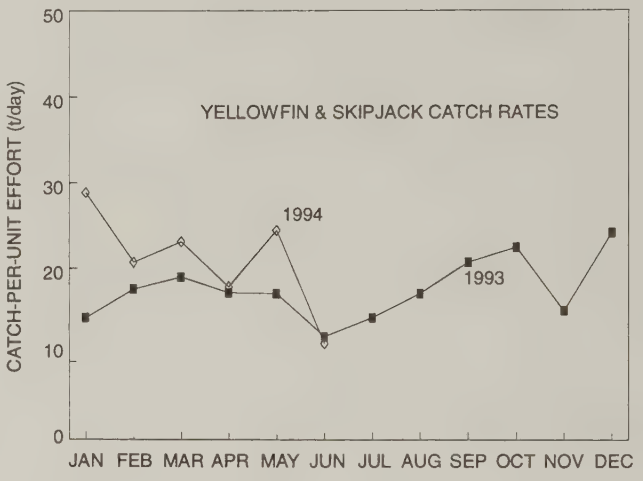

Figure 3. Yellowfin and skipjack catch rates (metric tons/day fished) for purse seiners fishing in the western Indian Ocean, 1993-94.

TIBURON LABORATORY

Tiburon, California

FISHERY MANAGEMENT ADVISORY

Hatcheries, Carrying Capacity and Chaos

The issue of carrying capacity has arisen frequently in recent informal discussions of maximum levels of hatchery production, both in the case of white seabass to be produced in southern California and chum salmon being produced in Hokkaido, Japan. Consistent with the fact that carrying capacity is an asymptotic limit to population size in the logistic model, there is a popular tendency to view

carrying capacity as an appropriate limit to planned hatchery production, above which level further production is thought to be inadvisable or possibly wasted. Investigation into simple population models shows that this concern with carrying capacity is mistaken.

Although relatively simple, the logistic model is a useful first approximation to more complicated population models. For the present purpose, it can be cast as an annual difference equation that allows prediction of next year's population size (N_{t+1}) from this year's population size (N_t):

$$N_{t+1} = N_t + rN_t(1-N_t/K),$$

where r is a maximum per capita rate of increase (a typical value might be 0.2, indicating a 20 percent maximum annual growth rate), and K is an asymptotic limit to abundance over time, also called the "carrying capacity." The terms on the right [rNt(1-Nt/K)] represent carryover of existing population and net increase or decrease due to combined rates of reproduction, mortality, growth, etc., some of which may be modified by effects of population size. Harvesting is not explicit. At carrying capacity (that is, Nt=K), this equation gives Nt+1 = Nt, indicating that the natural population has reached equilibrium abundance. From the viewpoint of hatchery production, we would like to know how a small increment in the present year's abundance will affect next year's abundance. This is the derivative dNt+1/dNt, which can be called the "subsequent-year value," and it describes what fraction of this year's hatchery production contributes to next year's population (Fig. 1). The subsequent-year value is unity at one-half of carrying capacity, and falls to 1-r at carrying capacity. Thus, in the typical case of r=0.2, the subsequent-year value of a hatchery-produced fish is still 80 percent when the receiving population is at carrying capacity. There is no sudden change in subsequent-year value at carrying capacity, and there is no major penalty for exceeding carrying capacity.

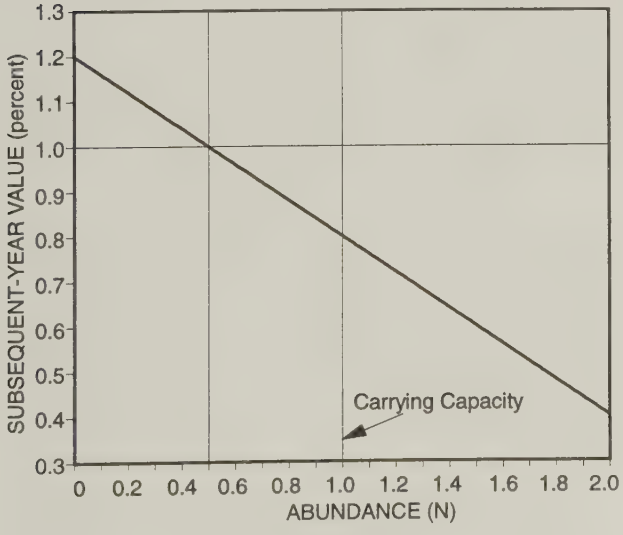

Figure 1. Subsequent-year value of hatchery-produced fish.

Instead of projecting one year into the future, we might consider the eventual equilibrium abundance if a constant level of hatchery output were maintained indefinitely. For example, the above 80 percent subsequent-year value would be compounded, producing an equilibrium long-term enhancement of five fish for each hatchery fish added annually to the population. Figure 2 shows the resulting abundance for increasing levels of hatchery production. While relative enhancement is substantial at lower levels of hatchery output, the bifurcations indicate population instability at higher levels of output. If hatchery output exceeds five times carrying capacity (5K), abundance begins to fluctuate in a limit cycle, and above 8K fluctuations enter the realm of so-called "chaos." This pattern is well known in the field of theoretical nonlinear dynamics, but this case is novel in that it produces chaos from the logistic model even at low values of *r*; previous models required *r*>2. From a practical viewpoint, it seems unlikely that high hatchery output into a real fish

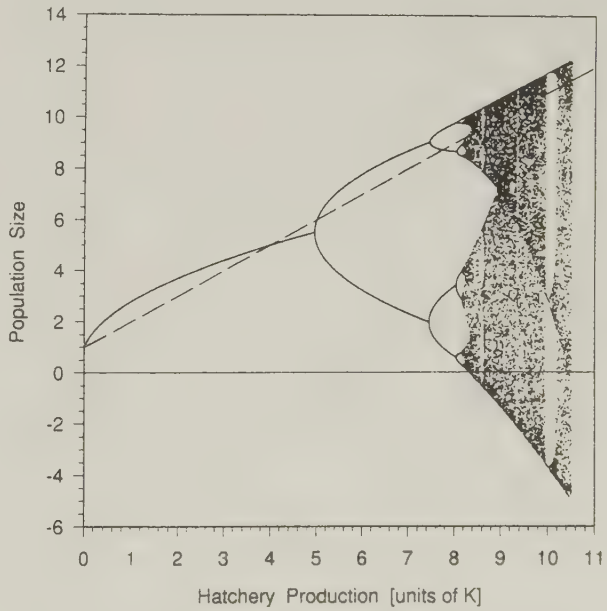

Figure 2. Abundance resulting from sustained large-scale hatchery production. Dashed line is natural abundance (K) plus one-year hatchery contribution.

population would result in this erratic behavior (negative population sizes are especially unrealistic!); however, it does serve as a reminder that unexpected consequences may arise if hatchery production is excessive. (A. MacCall, 415-435-3149)

GROUNDFISH COMMUNITIES INVESTIGATION

Decline in Yellow Tang on Kona Reefs

Assessments of reef communities along the Kona coast of the Island of Hawaii, made annually since 1986 by Fishery Biologists Ted Hobson, Tony Chess and Dan Howard, have been an extension of studies that Hobson has conducted at this location since 1969. Although the species composition of these communities has remained remarkably stable during this period, the most recent assessments have documented a decline in numbers of yellow tang, *Zebrasoma flavescens*. All evidence of this decline, however, has come from the reefs at Keei, in Kealakekua Bay. There has been no evidence of a decline at Honaunau, 6 km to the south, where the reefs have been similarly monitored over the same period. These findings are particularly noteworthy because visual counts had recorded similar numbers of yellow tang at both locations during all eight previous years of the program (Fig. 3). The yellow tang has been one of the three most numerous species during every assessment made at the Keei and Honaunau sites (the other two being the pomacentrid, *Chromis agilis*, and the acanthurid, *Ctenochaetus strigosus*), and its widespread decline on the Keei reefs was evident even to casual observations (Fig. 4a and 4b).

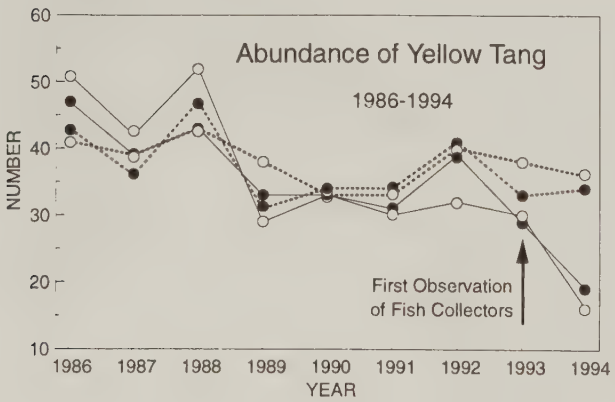

Figure 3. Results of counts of yellow tang at sites on the Kona coast of the Island of Hawaii during September or October, 1986 to 1994. Solid lines represent counts in two transects at Keei; dotted lines represent counts in two transects at Honaunau.

Figure 4a. A basalt-boulder habitat at Keei during 1979. The numerous light-hued fish are yellow tangs, which were consistently present at this location before 1994.

Figure 4b. The same location (shown in Fig. 4a) as it appeared during September 1994. The saddle-shaped boulder in the center of both photos has remained in place, but some of the others have moved. The large boulder in the right foreground may be the one at lower left in the 1979 view. This displacement shows how much these large boulders can be rolled about by storm surge.

This is a bright yellow fish highly valued by aquarists, and its decline at Keei may have resulted from removal of specimens by collectors in the tropical fish trade. That the two similarly abundant species noted above retained their numbers in the assessments may reflect their comparatively drab hues. Although fish collectors have been a highly controversial presence in the Kailua area for a number of years, none were seen at Keei by members of this Investigation until 1993. That year, however, a group of them were active in the vicinity of the study reefs during all ten days of the assessment.

That yellow tang have retained their numbers at the Honaunau site can be attributed to it being in a preserve, and thus off limits to collectors. Although most of Kealakekua Bay is a preserve, the Keei site is outside its borders.

Although it seems likely that the reduced numbers of yellow tang at Keei can be attributed to actions of collectors, it remains to be determined whether this reduction has lasting significance. Some preliminary data suggest that it may be a temporary condition, but this involves early juveniles and these have not been part of the annual assessments.

The obvious possibility suggested by these data is that removal of established yellow tang creates vacancies in the communities that are filled by recruits, and that without these vacancies, the recruits would not survive. This suggestion remains highly conjectural pending further study, however. (E. Hobson, 415-435-3149)

Pigmentation Pattern of Larval and Juvenile Stripetail Rockfish Described

Rockfish, *Sebastes* spp., recruitment is an important area of study at the Tiburon Laboratory. Due to the similarity of the rockfish larvae, the earliest estimates of recruitment have been limited in the past to the pelagic juveniles, where meristic counts were used to verify species identification. Recent efforts have increased the total number of species identified throughout their larval stages. This has allowed researchers to use larvae from certain rockfish species to predict recruitment strength, but many species are still unidentified.

Fishery Biologists Tom Laidig and Keith Sakuma have recently finished work on a manuscript describing the development of larval and juvenile stripetail rockfish, *S. saxicola* (Fig. 5). Large (10 mm) *S. saxicola* were identified using meristic characters and pigmentation. For fish <10 mm, initial identifications were accomplished using pigmentation. These identifications were confirmed through the use of otolith characters. *Sebastes saxicola* otoliths were compared to five other species that had similar pigment patterns at small sizes. The extrusion check radius of *S. saxicola* was approximately 11.9 microns, which was significantly different from the other species, confirming the identifications of the *S. saxicola*.

Researchers examined the similarity of *S. saxicola* to other *Sebastes* species. Also, the age and growth were examined and compared to other *Sebastes* species. (T. Laidig, 415-435-3149)

Figure 5. Larva of stripetail rockfish, *Sebastes saxicola*, 9.9 mm standard length.

GROUNDFISH ANALYSIS INVESTIGATION

Rockfish Recruitment Indices Compared

One of the main goals of research conducted at the Tiburon Laboratory during the last decade has been to estimate the reproductive success of rockfishes, *Sebastes* spp., inhabiting the central California coast. In one form or another, each of the three research investigations at the laboratory has contributed to this goal by surveying both young-of-the-year and adults of a number of different species, including shortbelly rockfish, *S. jordani;* blue rockfish, *S. mystinus;* and yellowtail rockfish, *S. flavidus*. A recent research paper, co-authored by Fishery Biologists Steve Ralston (of the Groundfish Analysis Task) and Dan Howard, (formerly of the Groundfish Communities Task) compared indices of year-class strength for blue and yellowtail rockfish based on offshore midwater trawl surveys and direct observations of settled young-of-the-year juveniles in nearshore habitats. Results showed good correspondence between the two methods of estimating reproductive success over broad spatial and temporal scales.

Data summarized in the Laboratory's recently completed "Progress in Rockfish Recruitment Studies" (Admin. Rep. T-94-01) afford the opportunity to compare year-class strength indices developed from the midwater trawl database and from the study of king salmon, *Oncorhynchus tshawytscha*, stomach contents. The trawl index is based upon annual surveys of pelagic juvenile abundance aboard the research vessel *David Starr Jordan* during the May-June time period. Pelagic juvenile trawl catches are first adjusted to a standard age of 100 days to correct for differences in length composition observed from one year to the next. The index is then calculated as the stratified mean

$\log_e$[catch/trawl+0.1]. The salmon stomach index is based on the occurrence of pelagic juvenile rockfish in the gut contents of this important coastal predator. King salmon are sampled from the recreational fishery from May to July and pelagic juveniles are enumerated for each rockfish species. Results are presented as the mean number of young-of-the-year rockfish per stomach examined.

A comparison of the two recruitment series over the 11-year period extending from 1983 to 1993 shows very good agreement between the two estimators of pelagic juvenile abundance. The data for total rockfish year-class strength were somewhat better correlated than were the species-specific data for shortbelly rockfish, *S. jordani* (Fig. 6). Both time series, however, captured the development of strong (1987 and 1988), moderate (1984, 1985, 1986, 1990 and 1991), and weak year classes (1983 and 1992). Both salmon stomach estimates for 1989 (that is, total rockfish and *S. jordani*) were highly influenced by several extremely large values, which may account for that year being off the trend line. The same is true for the 1993 *S. jordani* estimate. (S. Ralston and P. Adams, 415-435-3149)

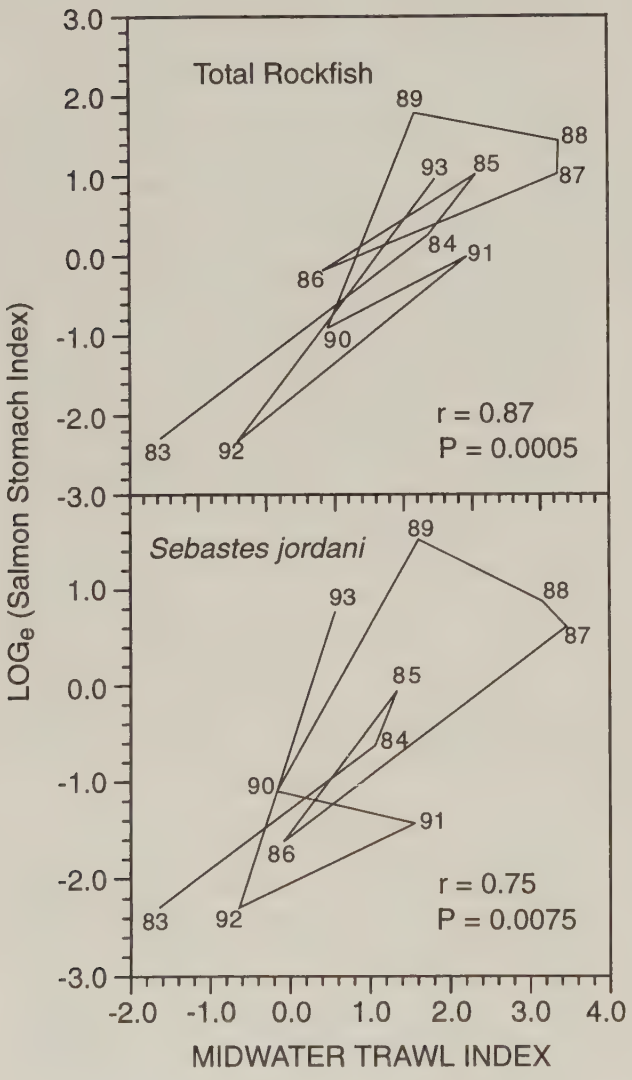

Figure 6. Scattergram time series of total rockfish and shortbelly rockfish, *Sebastes jordani*, year-class strength obtained from midwater trawl surveys and from examination of king salmon stomach contents.

GROUNDFISH PHYSIOLOGICAL ECOLOGY INVESTIGATION

YOY Juvenile Rockfish Growth and Feeding Study

For over a decade researchers at the Tiburon Laboratory have conducted field studies on the life history, distribution, relative abundance, and mortality of a variety of rockfish species, *Sebastes* spp., along the central California coast. In anticipation of in-depth experimental studies that will be designed to test hypotheses generated from field research, preliminary laboratory experiments were conducted at the University of California Bodega Marine Laboratory (BML) with copper rockfish, *Sebastes caurinus*, young-of-the-year (YOY) juveniles. The purpose of these experiments was to develop techniques for the their collection, handling, and rearing.

Live juvenile rockfish were beach seined from Bodega Bay, California, and transported to the BML. After one week's acclimation in 500-liter tanks, fish were anesthetized, weighed and measured, and distributed into 10-liter aquaria that were organized into duplicate daily food treatments of ad libitum ration frozen krill (*Euphausia pacifica*), low ration (10 percent bodyweight) frozen krill, ad libitum live adult shrimp (*Artemia*), and starvation (that is, 0 ration). All fish were weighed and measured at experiment days 1, 23, 57, and 83.

All *S. caurinus* were found to be remarkably resilient and adaptable to experimentation and handling. No mortalities occurred during the 83-day experiment, including the 0 ration fish. We believe at least some starved fish fed on micro-zooplankters that passed through the coarse seawater filters. Significant differences (ANOVA, $P \leq 0.01$) were found in juvenile fish growth among the different treatments. A posteriori pair-wise test indicated that no differences were found between the different food

treatments, but all food treatments resulted in significantly higher growth than in the starved fish. Fish in the 0 ration treatment exhibited no significant linear relationship between size (either length or weight) and time (that is, zero slope coefficient), and, thus, no measurable growth. Fed fish, in contrast, grew steadily throughout the study, averaging 0.19 cm/day and 0.04 g/day (Fig. 7).

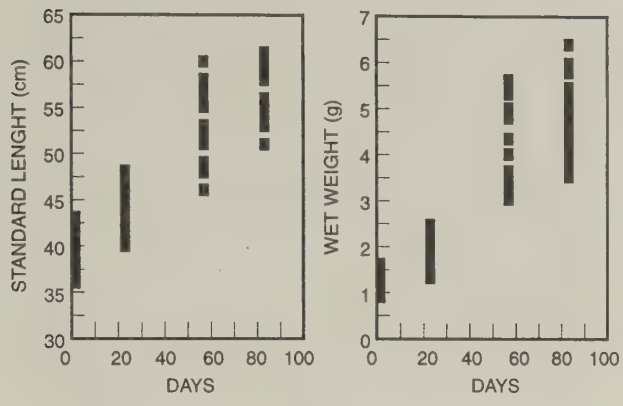

Figure 7. Growth of juvenile copper rockfish, *Sebastes caurinus*, in experimental aquaria.

Further analyses are underway to characterize starved and fed physiological conditions based on tissue protein and lipid content. YOY juvenile rockfish were found to grow and survive on a variety of food types and rations and scientists concluded that they are suitable for further use as experimental models. (M. Eldridge, 415-435-3149)

INFORMATION TECHNOLOGY SERVICES

La Jolla IT-95 Host Under Test and Implementation

The La Jolla IT-95 host was delivered on Thursday, November 17, to the Academic Computing Center, University of California San Diego (UCSD). The system, the Silicon Graphic Indigo, Challenge L series, was staged in the Control Data's Minneapolis, Minnesota, office before shipment to the UCSD site. During the week of November 21, the Control Data field engineer and the senior systems analyst installed the system, tested the Uninterruptible Power Supply, and ran the benchmark tests.

The Information Technology Services (ITS) staff, Matt Bones and Thanh Vu, matched the hardware and software order lists with the deliverables. Missing were the statistical analysis software package and other operation/user manuals. In answer to inquiries about SAS, Jackie Falls, NMFS IT-95 coordinator, stated that the SAS delivered to the other host sites was the beta version. The commercial version, which was available at the end of October, would be delivered within the next month. Receipt of the manuals is pending shipment by Control Data.

Rolf Schreiber from UCSD is an experienced UNIX Administrator managing the La Jolla system. In early December, ITS staff, Dorothy Roll, Rob Bistodeau, and Matt Bones, met with Schreiber to discuss the basic stipulations in the Facilities Management Services Agreement, the UCSD's system management responsibilities, and the Center's responsibilities. Matt Bones, the administrator for the ITS "sgilj" workstation, is the Center's liaison in contact with Schreiber to administer the users needs. As the liaison, Bones will establish and maintain the users accounts. The designated backup liaison and workstation administrator is Thanh Vu. Not covered under the facilities management contract is consulting on software applications. ITS will support that function.

The La Jolla host, named "ljswc," will be under a period of parallel testing with the UCSD VAX. During the onset, two ORACLE databases, which have been under development on workstations, will be loaded onto the host. Ken Wallace administers TUNA on the Pelagic Fisheries Resources Division's SUN System and Susan Jacobson administers CalCOFI on the ITS SUN ORACLE server. They each have their own method of administering the one relational database on their workstations. Because the Center's computer specialists are in the UNIX and ORACLE learning phases and inexperienced in administering multiple relational databases on a host, a Data Base Administrator (DBA) for the host will not be designated. The database administrative task will be the responsibility of a team: Ken Wallace, Susan Jacobson, Thanh Vu, and Matt Bones. Tasks such as assigning table space, monitoring the system, and optimizing performance will serve as an excellent training experience for each member of the team. (D. D. Roll, 619-546-7057)

PUBLICATIONS

Published

Balazs, G. H., P. Craig, B. R. Winton, and R. K. Miya. 1994. Satellite telemetry of green turtles nesting at French Frigate Shoals, Hawaii, and Rose Atoll, American Samoa. *In* Bjorndal, K. A., A. B. Bolten, D. A. Johnson, and Peter J. Eliazar (comps.), Proceedings of the Fourteenth Annual Symposium on Sea Turtle Biology and Conservation, March 1-5, 1994, Hilton Head, South Carolina, p. 184-187. U.S. Dep. Commer., NOAA Tech. Memo. NOAA-TM-NMFS-SEFSC-351.

———, W. C. Dudley, L. E. Hallacher, J. P. Coney, and S. K. Koga. 1994. Ecology and cultural significance of sea turtles at Punalu'u, Hawaii. *In* Bjorndal, K. A., A. B. Bolten, D. A. Johnson, and P. J. Eliazar (comps.), Proceedings of the Fourteenth Annual Symposium on Sea Turtle Biology and Conservation, March 1-5, 1994, Hilton Head, South Carolina, p. 10-13. U.S. Dep. Commer., NOAA Tech. Memo. NOAA-TM-NMFS-SEFSC-351.

———, D. Holts, and C. Brown. 1994. Evidence of interactions between high seas drift gillnet fisheries and the North American troll fishery for albacore, pp 214-227. *In* Shomura, R. S., J. Majkowski, and S. Langi (eds.), Food and Agriculture of the United Nations, Rome, Italy. Proceedings of the First FAO Expert Consultation on Interactions of Pacific Tuna Fisheries, 3-11 December 1991, Noumea, New Caledonia. Volume 1: Summary report and papers on interaction.

——— and T.J. Foreman. 1994. A review of the biology and fisheries for north Pacific albacore (*Thunnus alalunga*), pp. 173-187. *In* Shomura, R. S., J. Majkowski, and S. Langi (eds.), Food and Agriculture of the United Nations, Rome, Italy. Proceedings of the First FAO Expert Consultation on Interactions of Pacific Tuna Fisheries, 3-11 December 1991, Noumea, New Caledonia. Volume 2: Papers on biology and fisheries.

Becker, B. L., P. A. Ching, L. M. Hiruki, and S. A. Zur. 1994. The Hawaiian monk seal on Laysan Island, 1987 and 1989. U.S. Dep. Commer., NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-213, 20 p.

Brill, R. W. 1994. A review of temperature and oxygen tolerance studies of tunas pertinent to fisheries oceanography, movement models and stock assessments. Fish. Oceanogr. 3(3):204-216.

Detailed data on the physiological abilities and habitat requirements of some tuna species have now been collected. Laboratory and field studies show tunas are not strictly prisoners of their own thermoconserving mechanisms, but have rapid and extensive control over the efficacy of their vascular countercurrent heat exchangers. Skipjack tuna (*Katsuwonus pelamis*) are, therefore, probably not forced out of formerly suitable habitats as they grow because of the potential for overheating, as formerly thought. Because of their thermoregulatory ability, bigeye tuna (*Thunnus obesus*) apparently can exploit food resources well below the thermocline by minimizing rates of heat loss when diving into cold water, and then maximizing rates of heat gain from the environment during brief upward excursions into the warmer mixed layer.

Widely cited estimates of limiting oxygen levels, based on estimated metabolic rates at minimum hydrostatic equilibrium swimming speeds, are not accurate because tunas have high oxygen demands even at slow speeds. High metabolic rates, even at slow swimming speeds, most likely result from the high osmoregulatory costs engendered by tunas' large thin gills and/or their other adaptations for achieving exceptionally high maximum metabolic rates. Recent laboratory research and modelling efforts suggest the capacity of tunas' cardiorespiratory systems to deliver oxygen at extraordinarily high was evolved to allow rapid recovery from strenuous exercise, rapid digestion, and high rates of gonadal and somatic growth, rather, not high sustained cruising speeds. The rate at which reduced ambient oxygen levels prolong the time required for tunas to recover from strenuous exercise appears to be a good index of habitat suitability, with respect to oxygen.

Chave, E. H., and B. C. Mundy. 1994. Deep-sea benthic fish of the Hawaiian Archipelago, Cross Seamount, and Johnston Atoll. Pac. Sci. 48:367-409.

More than 250 benthic fish taxa were photographed and videotaped by Hawaii Undersea Research Laboratory submersibles at depths between 40 and 2000 m in the Hawaiian Archipelago, Johnston Atoll, and Cross Seamount. Most of the 213 identified fish species occurred close to hard substrates with holes, ledges, or caves. Twenty-two species (notably the larger sharks, lutjanids, and carangids) are cosmopolitan. Seventy-six species are restricted to various Indo-Pacific areas, 64 in the Pacific, and 51 in the Hawaiian Archipelago including Cross Seamount and Johnston Atoll. There is a rapid decrease in the number of species from 200 to 400 m depth. Eleven of the deeper-dwelling animals were found 20 m shallower than previously recorded. Faunal zones were not recognized at any depth. Species newly recorded in Hawaii include Bathypterois grallator (Goode & Bean), Bodianus cylindriatus (Tanaka), Centrophlorus cf. granulosus (Bloch & Schneider), Chaunax fimbriatus Hilgendorf, Caelorinchus spilonotus Sazonov & Iwamoto, Notocanthus sp., Paratrachichthys prosthemius Jordan & Fowler, Prognathodes guezei (Mauge & Bauchot), and Sladenia remiger Smith & Radcliffe. New species collected and reported elsewhere are Centrodraco rubellus Fricke et al., Epigonus glossodontus Gon, Owstonia sp., and Pseudanthias fucinus (Randall & Ralston). Caelorinchus sp. and Callanthias sp. are probably undescribed. It appears that the Hawaiian deep-sea fish fauna has multiple origins and affinities with many regions.

Coan, A. L., Jr. 1994. U.S.A. distant-water and artisanal fisheries for yellowfin tuna in the Central and Western Pacific, pp. 138-152. *In* Shomura, R. S., J. Majkowski, and S. Langi (eds.), Food and Agriculture of the United Nations, Rome, Italy. Proceedings of the First FAO Expert Consultation on Interactions of Pacific Tuna Fisheries, 3-11 December 1991, Noumea, New Caledonia. Volume 2: Papers on biology and fisheries.

Craig, M. P., J. L. Megyesi, C. S. Hall, J. L. Glueck, L. P. Laniawe, E. A. Delaney, S. S. Keefer, M. A. McDermond, M. Schulz, G. L. Nakai, B. L. Becker, L. M. Hiruki, and R. J. Morrow. 1994. The Hawaiian monk seal at French Frigate Shoals, 1990-91. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SWFSC-210, 70 p.

Graham, J. B., H. Dewar, N. C. Lai, K. E. Korsmeyer, P. A. Fields, T. Knower, R. E. Shadwick, R. Shabetai, and R. W. Brill. 1994. Swimming physiology of pelagic fishes. *In* Maddock, L., Q. Bone, and J. M. V. Rayner (eds.), Mechanics and physiology of animal swimming, p. 63-74. Cambridge University Press, Cambridge.

A large, portable water tunnel has permitted insight into the swimming physiology of sharks and tuna. Tunnel use has demonstrated the capacity of sharks to sustain swimming speeds of over one body length per second. This level of aerobic performance for sharks and the measured rates of oxygen consumption during swimming both exceed previous estimates for this group, and are similar to values reported for bony fishes. By permitting studies with stably swimming, instrumented sharks, the tunnel has enabled experimental analyses demonstrating the *vis a tergo* cardiac filling mechanism and the role of the pericardioperitoneal canal in facilitating rapid changes in cardiac stroke volume. For tunas, the tunnel has permitted long-term and replicate studies of metabolic rate and kinematics. With the incorporation of anaesthesia and surgical techniques it is now possible to investigate tuna cardiorespiratory responses to changes in temperature, oxygen, and swimming velocity, and to carry out biomechanical studies that include the timing of electromyograms at sites along the body, and measurement of muscle force generation in the lateral tail tendons during swimming.

Ito, R. Y., R. E. Dollar, and K. E. Kawamoto. 1994. The Hawaiian longline fishery for swordfish. (Abstract) International Symposium on Pacific Swordfish: Development of Fisheries, Markets, and Biological Research. Ensenada, Baja California, Mexico, December 11-14, 1994.

Kleiber, P. 1994. Types of tuna fishery interaction in the Pacific Ocean and methods of assessing interaction, pp. 61-73. *In* Shomura, R. S., J. Majkowski, and S. Langi (eds.), Food and Agriculture of the United Nations, Rome, Italy. Proceedings of the First FAO Expert Consultation on Interactions of Pacific Tuna Fisheries, 3-11 December 1991, Noumea, New Caledonia. Volume 1: Summary report and papers on interaction.

——— and A. Fonteneau. 1994. Assessment of skipjack fishery interaction in the eastern tropical Atlantic using tagging data, pp. 94-107. *In* Shomura, R. S., J. Majkowski, and S. Langi (eds.), Food and Agriculture of the United Nations, Rome, Italy. Proceedings of the First FAO Expert Consultation on Interactions of Pacific Tuna Fisheries, 3-11 December 1991, Noumea, New Caledonia. Volume 1: Summary report and papers on interaction.

——— and B. Baker. 1994. (Abstract) Assessment of interaction between North Pacific albacore, *Thunnus alalunga*, fisheries by use of a simulation model, p. 213. *In* Shomura, R. S., J. Majkowski, and S. Langi (eds.), Food and Agriculture of the United Nations, Rome, Italy. Proceedings of the First FAO Expert Consultation on Interactions of Pacific Tuna Fisheries, 3-11 December 1991, Noumea, New Caledonia. Volume 1: Summary report and papers on interaction.

Larson, R. J., W. H. Lenarz, and S. Ralston. 1994. The distribution of pelagic juvenile rockfish of the genus *Sebastes* in the upwelling region off central California. Calif. Coop. Oceanic Fish. Invest. Rep. 35:175-221.

Many species of central California rockfishes conclude their pelagic stage during the spring-summer upwelling period, when advection of surface waters could carry them away from nearshore postpelagic habitats. We examined the distributions of late-stage pelagic juvenile rockfish in April and May/June of 1987 and 1988, based on midwater-trawl surveys between Point Reyes and Monterey Bay, California. Distributional patterns were complex, and changed rapidly with changing oceanographic conditions and with changes in species and size composition. The smallest pelagic juveniles often appeared offshore, in the region of the upwelling front, which suggested that they had been advected offshore at some time during upwelling. However, few pelagic juveniles were found offshore of the upwelling front. Larger pelagic juveniles were often found close to shore, even when upwelling was active. This suggests that later-stage pelagic juveniles undergo behavioral changes that enable them to move toward shore or remain there in spite of upwelling. We also found evidence of more passive advection and retention of pelagic juveniles of all sizes, including onshore movement during relaxation of upwelling. It appears that relaxation of upwelling may be a sufficient but not necessary aspect of the settlement of juvenile rockfish from pelagic to postpelagic habitats. If so, advection during upwelling may not have a negative effect on the settlement and ultimate recruitment of rockfish.

Lau, B. B., and E. E. DeMartini. 1994. An evaluation of oocyte size in multiple regressions predicting gonad weight from body weight: a test using Hawaiian ehu, *Etelis carbunculus*. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SWFSC-212, 17 p.

Norton, J. G. D. R. Cayan, and D. R. McLain. 1994. Near and Distant Connection of Atmospheric Systems to

Ocean Temperature Change in the Coastal California Current Region In K.T. Redmond and V.L. Tharp, Eds. 1994. Proceedings of the Tenth Annual Pacific Climate (PACLIM) Workshop, April 4-7,1993. California Department of Water Resources, Interagency Ecological Studies Program Report 36.

Derivation of time series of ocean temperature change in the California current region for the spring-summer warming period complement earlier studies which focused on the fall-winter ocean cooling season. Connections between interannual fall-winter temperature changes in the coastal California current region and two widely separated locales of atmospheric forcing (North Pacific and equatorial Pacific) are shown by correlation tests. The fall-winter and spring-summer ocean temperature change series are compared to environmental anomalies and changes previously reported.

Assembly of the temporally complete ocean temperature series allows the various environmental events occurring over the 1954 -1986 period to be compared even though the original data on event intensity and duration is widely different. The newly developed series also allow some understanding of event forcing mechanisms to be derived from the oceanic response. The full ocean temperature change series are compared to atmospheric pressure fluctuations over the North Pacific north of 20° N.

——— and D. R. McLain. 1994. Diagnostic Patterns of Seasonal and Interannual Temperature Variation off the West Coast of the United States: Local and Remote Large Scale Atmospheric Forcing. J. Geophys. Res. 99(8):16019-16030.

Remote forcing from the Equatorial Pacific and local forcing from the North Pacific lead to interannual ocean temperature change along the west coast of the United States. In fall-winter seasons, coherent temperature changes extending from the surface to 300 m depth indicate remote forcing. Correlations between time series of ocean temperature change and series of equatorial sea level pressure (SLP) at 12.4° S x 130.9° E were as great below 100 m as at the surface. From 1954 to 1986, coherent warming events occurred only during moderate to strong El Niño years. Warming events more closely related to local North Pacific SLP at 45° N x 165° W have correlations which were greatest at the ocean surface.

The first three Empirical Orthogonal Functions (EOFs) derived from ocean temperature change series at 0, 100, 200, and 300 m accounted for more than 98% of the variance. The first EOF is most closely correlated with remote forcing and the second and third EOFs are closely correlated to local forcing. At the sea surface lags of up to six months were found for remote forcing while lags of less than three months were characteristic of local forcing. At 300 m there was an additional oceanic response which appears in phase with remote forcing. The study shows that interannual warming off the west coast has two distinguishable geographical origins and that the remotely generated warming signal arrives as complex dynamic structure having apparent propagation rates from 30 to greater than 200 km/day.

——— and S. J. Crooke. 1994. Occasional Availability of Dolphin, *Coryphaena hippurus*, to Southern California Commercial Passenger Fishing Vessel Anglers: Observations and Hypotheses. Calif. Coop. Oceanic Fish. Invest. Rep. 35:230-239.

Dolphin, *Coryphaena hippurus*, catch records from California based Commercial Passenger Fishing Vessels (CPFV) show that dolphin catch off southern California was more than 8% of the total southern and Baja California CPFV catch in 1983, 1984, 1990, 1992 and 1993. The major portion of the catch is off northern Baja California. Record catches for southern and Baja California were recorded in 1990 and 1992. Dolphin enter California waters under conditions that include elevated ocean temperatures and increased onshore and poleward coastal ocean transport. Large scale environmental events, that apparently increase dolphin abundance off southern California, appear related to regional decrease in eastern pacific high pressure system development. When the high pressure system is less intense, there is less southward wind along the coast. Consequently, California Current southward transport and coastal upwelling are decreased and the inshore counter current brings anomalously warm water into the southern California Bight. Local availability of kelp mat cover, along with local ocean processes are also likely to be important in aggregating dolphin and making them available to CPFV anglers.

Rogers, J. B. 1994. Preliminary status of the splitnose rockfish stock in 1994. Appendix H. *In* Status of the Pacific Coast groundfish fishery through 1994 and recommended acceptable biological catches for 1995. Pacific Fishery Management Council, Portland, Oregon.

Rosenfeld, L. K., F. B. Schwing, N. Garfield, and D. E. Tracy. 1994. Bifurcated flow from an upwelling center: a cold water source for Monterey Bay. Continental Shelf Research 14:931-964.

Sakuma, K., H. A. Parker, S. Ralston, F. B. Schwing, D. M. Husby, and E. M. Armstrong. 1994. The physical oceanography off the central California coast during February-March and May-June, 1992: A summary of CTD data from pelagic young-of-the-year rockfish surveys. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SWFSC-208, 169 p.

———, H. A. Parker, S. Ralston, F. B. Schwing, David M. Husby, and E. M. Armstrong. 1994. The physical oceanography off the central California coast during March and May-June, 1993: A summary of CTD data from pelagic young-of-the-year rockfish surveys. U.S.

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Schwing, F. B., and R. Mendelssohn. 1994. Evidence for increased coastal upwelling in the California Current System due to climate variability. EOS, Trans. Am. Geophys. Union. 75(44):346.

Skillman, R. A. 1994. Central Pacific swordfish status report. (Abstract) International Symposium on Pacific Swordfish: Development of Fisheries, Markets, and Biological Research. Ensenada, Baja California, Mexico, December 11-14, 1994.

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Fishery management that incorporates transferable, fractional licenses is examined as an alternative to the current program of limited permit transferability in the Hawaii longline fishery. Fractional licenses would accomplish the effort reduction that attrition of non-transferable permits was supposed to accomplish in this fishery, but without the inefficiencies, inequities, and uncertainties that have been encountered under the existing program.

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Little information exists on the biology of the demersal shark, *Squalus mitsukurii*. Recently, large numbers of this species were taken incidentally during research surveys conducted at Southeast Hancock Seamount in the central North Pacific Ocean. The information collected during 1985 to 1988 from these surveys is used to describe the life history, depth distribution, and biology of *S. mitsukurii*.

Bathymetric distributional patterns of female and male *S. mitsukurii* differed slightly, although bottom longline catches revealed a depth distribution from the summit (260 m) to 740 m for both sexes. Males generally were found deeper than females. In addition, the size of males generally increased with depth whereas no apparent trend was observed for females.

Reproductive parameters for both sexes are presented. Males tended to reach maturity at smaller sizes than did females. Gravid females had broods of up to six uterine embryos. Length of young close to parturition was 21-16 cm.

Tentative estimates of age and growth were made from dorsal spine increment counts. Maximum ages were 27 years for females and 18 years for males. Females exhibited more rapid growth than males after about age 9.

The diet of *S. mitsukurii* included both benthic and mesopelagic prey. Fishes, cephalopods, and crustaceans were the major components of the diet.

Comparison of the biological characteristics suggest that this species is probably typical of other slow-growing, low fecund members of the genus *Squalus*. The 50 percent decline in catch rates observed during this study suggests that the number of *S. mitsukurii* on the seamount declined dramatically, possibly as a result of overfishing.

Approved by Science and Research Director, SWR

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